

## SPECIFICATION

Device and Method for Supplying Gas while Dividing to Chamber  
from Gas Supplying Facility Equipped with Flow Controller

Field of the Invention

[0001] The present invention is to be used for semiconductor manufacturing facilities, and is concerned with improvements in supplying gas while automatically dividing to a chamber from a gas supplying facility equipped with a flow controller.

Background of the Invention

[0002] A device called a pressure type flow controller has been widely used for flow control of gas to be supplied to a chamber of a semiconductor manufacturing facility.

Figure 5 illustrates an example in the event that processing gas G is supplied into a chamber to form a silicon oxide film using a pressure type flow controller FCS. A specified quantity Q of processing gas G is supplied to a pressure-reduced chamber C by using a vacuum pump Vp, and a quantity Q of processing gas G is discharged to a wafer H on the supporting device I through a gas discharger D.

[0003] On the other hand, the afore-mentioned pressure type flow controller FCS utilizes the relation that "when a critical condition  $P_1 > \text{approx. } 2 \times P_2$  is maintained, a quantity Q of gas passing through an orifice L is determined only by gas pressure  $P_1$  on the upstream side of the orifice, and is represented by the formula  $Q = CP_1$  (where C is a constant dependent on the bore of the orifice L and gas temperature)", thus a quantity Q on the downstream side of the orifice L

being able to be held at a desired set value by regulating the afore-mentioned pressure  $P_1$  with a control valve CV.

With Figure 5,  $P_0$  designates supply pressure of processing gas G,  $P_m$  a manometer, F a filter, CPU a central processing unit,  $Q_s$  an input signal for a flow rate setting, and  $Q_e$  an output signal for control of the flow rate.

A pressure type flow controller itself has been publicly disclosed with the TOKU-KAI-HEI No.8-338546, the TOKU-KAI-HEI No.11-63265 and others. Therefore, detailed explanations are omitted herewith.

[0004] With the afore-mentioned flow controller FSC, it becomes an essential condition that, as stated above, gas pressure  $P_1$  on the upstream side of the orifice and gas pressure  $P_2$  on the downstream side of the orifice are within the afore-mentioned critical condition. The drawback is that the flow control cannot be performed because the critical expansion pressure condition is not satisfied, for example, when gas pressure  $P_2$  on the downstream side of the orifice rises more than gas pressure  $P_1$  on the upstream side of the orifice.

Another drawback is that flow control accuracy is lowered in reality when  $P_1/P_2$  reaches closer the limit value of the afore-mentioned critical pressure condition with the rise of pressure  $P_2$  on the downstream side of the orifice. Thus limiting the flow control range capable of being used when pressure  $P_2$  on the downstream side rises.

[0005] As above, various drawbacks are seen with the control of the gas flow rate by the pressure type flow controller when pressure  $P_2$  on the downstream side of the orifice L rises. However, the gas supply method to a chamber by using the said pressure type flow controller FCS allows the gas flow control with

the high degree of accuracy easily to be performed, and makes it possible that a pressure regulating device with the high degree of accuracy at the gas supply source is not required to be provided, thus allowing considerable reductions of the costs in a gas supply facility, to achieve excellent, practical effects.

[0006] On the other hand, a silicon wafer with a larger external diameter has been used for semiconductor manufacturing in recent years. In the case of the wafer H with an external diameter of 300mm  $\phi$ , for example, there are required separate adjustments for supply quantities of processing gas to the center part and the peripheral (edge) part respectively.

As a measure to handle the matter, processing gas can be supplied to the afore-mentioned center part and edge part respectively by providing separate branch supply lines GL<sub>1</sub> and GL<sub>2</sub> as shown in Figure 6, thus being able to supply processing gas G without any difficulties from a gas supply source S with specified quantities Q<sub>1</sub> and Q<sub>2</sub> even with gas supply lines GL<sub>1</sub> and GL<sub>2</sub> wherewith a pressure type flow controller FCS.

[0007] However, to supply gas using gas supply lines GL<sub>1</sub> and GL<sub>2</sub> both of which are equipped with a pressure type flow controller FCS<sub>1</sub> and FCS<sub>2</sub> independently into a chamber invites a rise in installation costs as well as upsizing of a semiconductor manufacturing facility, and is also found to be time-consuming for its maintenance. For these reasons, the method is undesirable.

[0008] To solve these problem, as shown in Figure 7, it is found desirable that the method wherewith flow rate Q<sub>1</sub> and Q<sub>2</sub> of branch gas supply lines GL<sub>1</sub> and GL<sub>2</sub> are controlled by branching two gas supply lines GL<sub>1</sub> and GL<sub>2</sub> from a

pressure type flow controller FCS, and regulating flow rate control valves  $V_1$  and  $V_2$  equipped with the gas supply lines  $GL_1$  and  $GL_2$  respectively is employed.

[0009] Among the general-purpose pressure type flow controllers FCS for a gas supply facility presently used, ones with flow rate control characteristics capable of being used within the range of 0~100Torr of pressure  $P_2$  on the downstream side of the orifice under optimum conditions have been widely employed in general. Accordingly, with these pressure type flow controllers FCS, the flow rate control range is considerably limited when pressure  $P_2$  on the downstream side of the orifice exceeds approximately 100Torr, as described above, from the point of flow rate accuracy.

[0010] For example, let's assume that processing gas G of a flow rate  $Q=300\text{SCCM}$  is to be supplied to a chamber C through supply lines  $GL_1$  and  $GL_2$  at flow rates of  $Q_1=130\text{SCCM}$  and  $Q_2=170\text{SCCM}$  in Figure 7. With a gas supply facility not equipped with a pressure type flow controller FCS, firstly flow rate control valves  $V_1$  and  $V_2$  are closed, and next, the flow rate of processing gas is set to  $Q=300\text{SCCM}$ , and then flow rates  $Q_1$  and  $Q_2$  can be adjusted to the set value by regulating the degree of opening of control valves  $V_1$  and  $V_2$  automatically or with reference of a flow meter (not illustrated).

[0011] However, in the event that a pressure type flow controller FCS is used for a flow controller of the gas supply facility as illustrated in Figure 7, both control valves  $V_1$  and  $V_2$  are first placed in a state of being fully closed, and a flow rate  $Q$  ( $300\text{SCCM}$ ) of the pressure type flow controller FCS is set. Then, the degree of opening of both control valves  $V_1$  and  $V_2$  are adjusted to the flow rate  $Q_1$  ( $130\text{SCCM}$ ) and  $Q_2$  ( $170\text{SCCM}$ ) for branch supply lines  $GL_1$  and  $GL_2$ .

This, however, finds it difficult to control the flow rates accurately and quickly.

The reasons are that there is a possibility that the values of  $P_1/P_2$  are out of the threshold value of critical pressure conditions of the afore-mentioned pressure type flow controller FCS due to the rise of pressure  $P_2$  on the upstream side of both control valves  $V_1$  and  $V_2$  when opening of  $V_1$  and  $V_2$  are small, thus resulting in that the control flow rate  $Q$  with the pressure type flow controller FCS becomes vastly different from the set flow rate of  $Q=300\text{SCCM}$ .

[0012] To solve the afore-mentioned difficulties, inventors of the present invention have applied for a patent, the TOKU-GAN-HEI No.2002-161086 by developing a method to supply gas while dividing gas into a chamber from a gas supply facility.

[0013] This is a completely new idea of switching from the conventional and well-worn method wherewith gas from a gas supply facility is supplied while dividing for being controlled, that is, flow rate control valves  $V_1$  and  $V_2$  provided with branch supply lines are put in a state of fully or near-fully closing, and then, both flow rate control valves  $V_1$  and  $V_2$  are gradually opened, while with the new method both flow rate control valves  $V_1$  and  $V_2$  are made to be in a state of fully or near-fully opening, and then, both flow rate control valves  $V_1$  and  $V_2$  are regulated to the direction of closing step by step for the opening adjustment, thus making it possible that while a total flow quantity  $Q$  is controlled at the high degree of accuracy with the pressure type flow controller FCS, flow rates  $Q_1$  and  $Q_2$  are controlled by the pressure type division quantity controllers  $FV_1$  and  $FV_2$  provided with branch supply lines  $GL_1$  and  $GL_2$  at a desired flow rate ratio  $Q_1/Q_2$  accurately and quickly.

[0014] With the method, there will be no possibility that pressure  $P_2$  on the downstream side of the orifice of the pressure type flow controller FCS rises sharply at the time of being divided even with processing gas from a gas supply facility provided with a pressure type flow controller FCS, thus making it possible that the total quantity  $Q$  is accurately controlled at a desired flow rate value  $Q$  regardless of the flow control while dividing by means of a pressure type division quantity controllers  $FV_1$  and  $FV_2$ . Accordingly, excellent characteristics of a pressure type flow controller FCS can be utilized, thus making it possible that the flow division control while dividing is performed accurately and quickly, and also with a plurality of flow rate ratios  $Q_2/Q_1$ .

[0015] As stated above, the method employed in the TOKU-GAN-HEI No.2002-161086 made it possible that flow rates  $Q_1$  and  $Q_2$  of branch supply lines  $GL_1$  and  $GL_2$  are regulated at a desired flow rate ratio  $Q_1/Q_2$  accurately and quickly. However, on the other hand, the method made the control complicated because it employed two pressure type division quantity controllers  $FV_1$  and  $FV_2$  beside a pressure type flow controller FCS for regulating pressure on both sides, thus inviting another problem of facility costs becoming higher.

Patent Literature 1: TOKU-KAI-HEI No.8-338546 Public Bulletin

Patent Literature 2: TOKU-KAI-HEI No.11-63265 Public Bulletin

### Disclosure of the Invention

#### Object of the Invention

[0016] It is an object of the present invention to solve a problem that, with a conventional method wherewith gas is supplied while dividing to a chamber from a gas supply facility as illustrated in Figure 7, flow rate control accuracy is

lowered when critical pressure conditions are out of a threshold values due to that pressure  $P_2$  on the upstream side of control valves  $V_1$  and  $V_2$  rises in the event that the degree of opening of control valves  $V_1$  and  $V_2$  are small.

It is also another object of the present invention to solve a problem that, with techniques newly developed with the TOKU-GAN-HEI No.2002-161086, two pressure type division quantity controllers  $FV_1$  and  $FV_2$  are required beside a pressure type flow controller FCS, thus inviting high facility costs and making flow control complicated.

#### Means to Achieve the Objects

[0017] To solve the afore-mentioned problems, inventors of the present invention have developed a device and a method, simply structured and manufactured at low costs, for supplying gas while dividing to a chamber from a gas supply facility accurately and quickly.

[0018] The present invention as claimed in Claim 1 is fundamentally so constituted that, with a device for supplying a specified quantity  $Q$  of gas  $G$  while dividing at a specified flow rate ratio  $Q_1/Q_2$  from a gas supply facility 1 provided with a flow controller QCS into a chamber  $C$  through a plurality of branch supply lines  $GL_1$  and  $GL_2$  and shower plates 3 and 4 fixed to the ends thereof, open/close valves  $OV_1$  and  $OV_2$  are provided with an afore-mentioned plurality of branch supply lines  $GL_1$  and  $GL_2$  respectively, and also a bypass line  $BL_1$  on the downstream side of an open/close valve  $OV_1$  and branched from the branch supply line  $GL_1$ , a bypass line  $BL_2$  on the downstream side of an open/close valve  $OV_2$  and branched from the branch supply line  $GL_2$ , a pressure type division quantity controller  $FV$  connected to the afore-mentioned bypass lines

BL<sub>1</sub> and BL<sub>2</sub>, a pressure sensor PS<sub>1</sub> to measure pressure inside the branch supply line GL<sub>1</sub>, and a pressure sensor PS<sub>2</sub> to measure pressure inside the branch supply line GL<sub>2</sub> are provided.

[0019] The present invention as claimed in Claim 2 according to Claim 1 is fundamentally so constituted that a control device CT to regulate the degree of opening of a pressure type division quantity controller FV is provided to reduce the difference between actual pressure of the branch supply line and set pressure to reach the specified flow rate ratio  $Q_1/Q_2$  by comparing either one of set pressure PI<sub>1</sub> or PI<sub>2</sub> of the branch supply lines GL<sub>1</sub> and GL<sub>2</sub> to reach the specified flow rate ratio  $Q_1/Q_2$  with corresponding actual pressure PT<sub>1</sub> or PT<sub>2</sub> of the branch supply lines GL<sub>1</sub> or GL<sub>2</sub> measured by the pressure sensor PS<sub>1</sub> or the pressure sensor PS<sub>2</sub>.

[0020] The present invention as claimed in Claim 3 according to Claim 1 or Claim 2 is fundamentally so constituted that an open/close valve OV<sub>1</sub> and an open/close valve OV<sub>2</sub> are pneumatically operated, and a switch valve SV is provided for supplying actuating air to the open/close valve OV<sub>1</sub> and the open/close valve OV<sub>2</sub>.

[0021] The present invention as claimed in Claim 4 according to Claim 1, Claim 2 or Claim 3 is fundamentally so constituted that an open/close valve OV<sub>1</sub> and an open/close valve OV<sub>2</sub> are made to be integrated.

[0022] The present invention as claimed in Claim 5 according to Claim 1, Claim 2, Claim 3 or Claim 4 is fundamentally so constituted that a pressure type flow controller FCS is used for a flow controller QCS.

[0023] The present invention as claimed in Claim 6 is fundamentally so



constituted that, with a method for supplying a specified quantity  $Q$  of gas  $G$  while dividing at a specified flow rate ratio  $Q_1/Q_2$  from a gas supply facility 1 provided with a flow controller QCS into a chamber  $C$  through a plurality of branch supply lines  $GL_1$  and  $GL_2$  and shower plates 3 and 4 fixed to the ends thereof, open/close valves  $OV_1$  and  $OV_2$  are installed on an afore-mentioned plurality of branch supply lines  $GL_1$  and  $GL_2$  respectively, and also a bypass line  $BL_1$  on the downstream side of an open/close valve  $OV_1$  and branched from the branch supply line  $GL_1$ , a bypass line  $BL_2$  on the downstream side of an open/close valve  $OV_2$  and branched from the branch supply line  $GL_2$ , a pressure type division quantity controller  $FV$  connected to the afore-mentioned bypass lines  $BL_1$  and  $BL_2$ , and further a pressure sensor  $PS_1$  to measure pressure inside the branch supply line  $GL_1$ , and a pressure sensor  $PS_2$  to measure pressure inside the branch supply line  $GL_2$  are provided so that a total quantity  $Q=Q_1+Q_2$  of gas is supplied while dividing into a chamber  $C$  at desired division quantities  $Q_1$  and  $Q_2$  by opening the open/close valve of the branch supply line which has a larger flow rate to regulate the degree of opening of the afore-mentioned pressure type division quantity controller  $FV$ , and adjusting the flow rate of the branch supply line which has the larger flow rate to the branch supply line which has the smaller flow rate, thus regulating pressure in the branch supply line  $GL_1$  and the branch supply line  $GL_2$ .

[0024] The present invention as claimed in Claim 7 according to Claim 6 is so made that the degree of opening of a pressure type division quantity controller  $FV$  is regulated to reduce the difference between actual pressure of a branch supply line and set pressure to reach a specified flow rate ratio  $Q_1/Q_2$  by

comparing either one of set pressure  $PI_1$  or  $PI_2$  of branch supply lines  $GL_1$  and  $GL_2$  to reach the specified flow rate ratio  $Q_1/Q_2$  with corresponding actual pressure  $PT_1$  or  $PT_2$  of the branch supply lines  $GL_1$  and  $GL_2$  measured by the pressure sensor  $PS_1$  or the pressure sensor  $PS_2$ .

[0025] The present invention as claimed in Claim 8 according to Claim 6 or Claim 7 is so made that an open/close valve  $OV_1$  and an open/close valve  $OV_2$  are pneumatically operated, and a switch valve  $SV$  is provided for supplying actuating air to the open/close valve  $OV_1$  and the open/close valve  $OV_2$  so that the open/close valve of the branch supply line with the larger supply quantity is made open by the switch valve  $SV$ .

[0026] The present invention as claimed in Claim 9 according to Claim 6, Claim 7 or Claim 8 is so made that a pressure type flow controller is used for a flow controller  $QCS$ .

#### Effects of the Invention

[0027] The present invention provides a device for supplying gas while dividing to a chamber from a gas supply facility equipped with a flow controller which is so constituted that, with a device for supplying a specified quantity  $Q$  of processing gas while dividing at a specified flow rate ratio  $Q_2/Q_1$  from a gas supply facility 1 equipped with a flow controller  $QCS$  into a chamber  $C$  through a plurality of branch supply lines  $GL_1$  and  $GL_2$  and shower plates 3 and 4 fixed to the ends thereof, a division quantity controller 2 comprising an open/close valves  $OV_1$  and  $OV_2$  installed on an afore-mentioned plurality of branch supply lines  $GL_1$  and  $GL_2$  respectively, a bypass line  $BL_1$  branched from a branch supply line  $GL_1$  on the downstream side of the open/close valve  $OV_1$ , a bypass line  $BL_2$

branched from a branch supply line GL2 on the downstream side of the open/close valve OV2, a pressure type division quantity controller FV connected to the bypass line BL1 and the bypass line BL2, a pressure sensor PS1 to measure pressure inside the branch supply line GL1, and a pressure sensor PS2 to measure pressure inside the branch supply line GL2 is installed between the afore-mentioned gas supply facility 1 and a chamber C so that a specified quantity Q of gas is supplied while dividing into the chamber at a specified flow rate ratio  $Q_1/Q_2$  through shower plates 3 and 4 fixed to the ends of branch supply lines GL1 and GL2.

As a result, pressure control on a number of flow rate ratios  $Q_2/Q_1$  becomes possible accurately and quickly with the pressure type division quantity controller, thus achieving an excellent effect of making facility costs lowered. [0028]. The present invention provides a method for supplying gas while dividing to a chamber from a gas supply facility equipped with a flow controller characterized by that, with a method for supplying a specified quantity Q of processing gas while dividing at a specified flow rate ratio  $Q_1/Q_2$  from a gas supply facility 1 equipped with a flow controller QCS into a chamber through a plurality of branch supply lines GL1 and GL2 and shower plates 3 and 4 fixed to the ends thereof, a division quantity controller 2 comprising an open/close valves OV1 and OV2 installed on an afore-mentioned plurality of branch supply lines GL1 and GL2 respectively, a bypass line BL1 branched from a branch supply line GL1 on the downstream side of the open/close valve OV1, bypass line BL2 branched from a branch supply line GL2, a pressure type division quantity controller FV connected to the bypass line BL1 and the bypass line BL2, a

pressure sensor PS<sub>1</sub> to measure pressure inside the branch supply line GL<sub>1</sub>, and a pressure sensor PS<sub>2</sub> to measure pressure inside the branch supply line GL<sub>2</sub> is installed between the afore-mentioned gas supply facility 1 and a chamber C, and also that a total quantity  $Q=Q_1+Q_2$  of gas while dividing is supplied into the afore-mentioned chamber C at desired flow rates  $Q_1$  and  $Q_2$  by regulating pressure of the branch supply line GL<sub>1</sub> and the branch supply line GL<sub>2</sub> by opening the open/close valve of a branch supply line having a larger flow, to adjust the degree of opening of the afore-mentioned pressure type division quantity controller FV, thus adjusting a flow rate of gas running from a branch supply line having a larger flow rate of supply to a branch supply line having a smaller flow rate of supply, to regulate pressure of the branch supply line GL<sub>1</sub> and the branch supply line GL<sub>2</sub>.

As a result, pressure control on a number of flow rate ratios  $Q_2/Q_1$  can be performed accurately and quickly with one set of pressure type division quantity controller, thus achieving excellent effects of making facility costs lowered and pressure control easier.

#### Brief Description of the Drawings

[0029] Figure 1 is an overall schematic diagram to explain a device and a method for supplying gas while dividing to a chamber from a gas supply facility equipped with a flow controller according to the present invention.

Figure 2 is a basic block diagram of a pressure type division quantity controller FV.

Figure 3 is lines (computed values) to illustrate the relations between set pressure (PI<sub>1</sub> and PI<sub>2</sub>) and a division flow rate ratio  $Q_2/Q_1$  in the event that

shower plated 3 and 4 to be used are made to be a Pattern 1 with supply while dividing in Figure 1.

Figure 4 is lines (computed values) to illustrate the same relations in the event that shower plates 3 and 4 to be used are made to be a Pattern 2 as with Figure 3.

Figure 5 is an explanatory drawing to show a method for supplying processing gas to a chamber by using a conventional pressure type flow controller FCS.

Figure 6 is an explanatory drawing to show the case wherein processing gas is supplied to a chamber C from a single gas supply source S by using a plurality of pressure type flow controllers.

Figure 7 is an explanatory drawing to show the case wherein processing gas is supplied to a chamber C from a gas supply source equipped with a pressure type flow controller by using control valves.

#### List of Reference Characters and Numerals

[0030] BL<sub>1</sub> · BL<sub>2</sub> Bypass lines

C Chamber

D Gas discharger

Dc Gas discharger for the center part

De Gas discharger for the edge part

FV Pressure type division quantity controller

GL<sub>1</sub> Branch supply line for the center part

GL<sub>2</sub> Branch supply line for the edge part

OV<sub>1</sub> · OV<sub>2</sub> Open/close valves

PT<sub>1</sub> · PT<sub>2</sub> Pressure in branch supply lines

P Pressure inside a chamber

PS<sub>1</sub> · PS<sub>2</sub> Pressure sensors of branch supply lines

QCS Flow controller

SV Electric switch valve

1 Gas supply facility

2 Division quantity controller

3 Shower plate of a gas discharger for the center part

3a Orifice hole made in a shower plate

4 Shower plate of a gas discharger for the edge part

4a Orifice hole made in a shower plate

#### Best Mode to Carry Out the Invention

[0031] The embodiment in accordance with the present invention is described hereunder with reference to the drawings.

Figure 1 is an overall schematic diagram to explain a device and a method for supplying gas while dividing to a chamber from a gas supply facility equipped with a flow controller QCS according to the present invention. In Figure 1, a gas supply facility 1 comprises a supply source S of processing gas G, a gas main valve V<sub>0</sub>, a flow controller QCS and the like. A division quantity controller 2 comprises a pressure type division quantity controller FV, a communication control circuit CT and the like.

[0032] Further, in Figure 1, C designates a chamber, D a gas discharger, D<sub>c</sub> a gas discharger for the center part, D<sub>e</sub> a gas discharger for the edge part, GL<sub>1</sub> a branch supply line for the center part, GL<sub>2</sub> a branch supply line for the edge part,

Q a total quantity of gas,  $Q_1 \cdot Q_2$  flow rates while dividing,  $PT_1 \cdot PT_2$  pressure in branch supply lines  $GL_1$  and  $GL_2$ ,  $P_3$  pressure inside a chamber C,  $PS_1 \cdot PS_2$  pressure sensors of branch supply lines  $GL_1$  and  $GL_2$ , 3 a shower plate of a gas discharger Dc for the center part, 3a an orifice hole made on the shower plate, 4 shower plate of a gas discharger De for the edge part, and 4a an orifice hole made on the shower plate.

[0033] In addition, in Figure 1,  $EL_1 \cdot EL_2$  designate signal connection lines of a communication control circuit CT with pressure sensors  $PS_1$  and  $PS_2$ ,  $EL_3$  a signal connection line of a communication control circuit with an electric switch valve SV, and T1 a power source/signal input terminal.

[0034] The afore-mentioned gas supply facility 1 comprises a processing gas supply source S, a plurality of flow controllers QCS and the like. Any type flow controllers QCS can be employed as a flow controller QCS as long as it functions accurately and quickly. A pressure type flow controller FCS illustrated in the afore-shown Figure 5 has been used herewith for a flow controller QCS. When a specified flow rate setting signal  $Q_s$  is inputted to a control unit (CPU), pressure  $P_1$  on the upstream side of an orifice L is regulated by a control valve CV so that a flow rate Q on the downstream side is automatically adjusted to the set flow rate  $Q_s$ .

Also, a control flow rate output signal  $Q_e$  corresponding to the adjusted flow rate is outputted from the control unit (CPU). If it is found that the deviation between the flow rate setting input signal  $Q_s$  and the afore-mentioned control flow rate setting signal  $Q_e$  exceeds the prescribed time, an input/output deviation abnormality signal is transmitted from the CPU (not illustrated in Figure

5) as stated later.

[0035] The afore-mentioned division quantity controller 2 comprises a plural number of open/close valves  $OV_1$  and  $OV_2$ , a pressure type division quantity controller FV, a communication control circuit CT to control these, an electric switch valve SV for opening and closing of  $OV_1$  and  $OV_2$ , orifice plates 3 and 4 connected to the ends of branch supply lines, and the like.

[0036] As shown in Figure 2, the afore-mentioned pressure type division quantity controller comprises a control valve CV, a driving control part (CPU) for the control valve CV and the like, to regulate the degree of opening of the control valve CV through the mediation of the driving unit part (CPU) with the control signal inputted CT through the line EL3 from the communication circuit CT.

With the embodiment in Figure 2, a piezo-driving stroke amplification type metal diaphragm valve is employed for a control valve CV of the afore-mentioned pressure type division quantity controller FV so that it is easily adaptable even when the flow rates  $Q_1$  and  $Q_2$  are large.

[0037] When processing gas G is supplied into a chamber C through orifice holes 3a and 4a made on shower plates 3 and 4 respectively, division quantities  $Q_1$  and  $Q_2$  can be controlled, as in the case of the orifice of a flow controller QCS, that is, a division quantity  $Q_1$  is controlled with a formula  $Q_1 = C_1 P_{l1}$  by adjusting  $P_{l1}$  if the relationships  $P_{l1} > 2P_3$  are maintained between pressure  $P_3$  inside a chamber C and pressure  $P_{l1}$  on the upstream side of the orifice hole 3a of the orifice plate 3 for the center part.

Similarly, a division quantity  $Q_2$  is controlled with a formula  $Q_2 = C_2 P_{l2}$  by  $P_{l2}$  if the relationships  $P_{l2} > 2P_3$  are maintained between pressure  $P_3$  inside a



chamber C and pressure  $PI_2$  on the upstream side of the orifice hole 4a of the shower plate 4 for the edge part, (where  $C_1$  and  $C_2$  are constants dependent on the cross-sectional areas of the orifice holes 3a and 4a, their shapes or gas temperature).

[0038] Referring to Figure 1, the afore-mentioned communication control circuit CT is provided with a power source/signal input terminal  $T_1$ , and connected to a pressure type division quantity controller FV and an electric switch valve through the mediation of signal connection lines  $EL_3$  and  $EL_4$ .

[0039] An open/close valve OV is pneumatically operated. It is of a normal open type wherewith it is open under a state of driving air not being supplied, but both open/close valves  $OV_1$  and  $OV_2$  are normally being closed when a division quantity controller.2 is in a state of halting.

[0040] When a starting signal, a total flow quantity  $Q$ , a desire flow rate ratio  $Q_2/Q_1$ , a combination pattern of shower plates 3 and 4 and the like are inputted through the mediation of the power source/signal input terminal  $T_1$ , a communication control circuit CT makes the branch supply line with pressure set low out of set pressure  $PI_1$  and  $PI_2$  a subject-to-control branch supply line, while the remaining branch supply line a non-subject-to-control branch supply line as patterns of set pressure ratio  $PI_2/PI_1$  show in Table 1.

A communication control circuit CT opens an open/close valve of the non-subject-to-control branch supply line while it closes an open/close valve of the subject-to-control branch supply line.

Further, a communication control circuit CT determines values  $Q_1$  and  $Q_2$  with given total flow quantity  $Q$  and flow rate ratio.

[0041] [Table 1]

Set Pressure Ratio – Subject-to-control

Open/close valves operation command

Set pressure ratio $PI_2/PI_1$	Subject-to-control	Open/close valve operation command	
		OV <sub>1</sub>	OV <sub>2</sub>
> 1	PI <sub>1</sub>	Close	Open
= 1	NONE	Open	Open
< 1	PI <sub>2</sub>	Open	Close

[0042] By inputting a specified signal to the communication control circuit CT, pressure PT on the subject-to-control branch supply line side is regulated with the pressure type quantity controller FV.

Namely, a communication control circuit CT starts comparing set values with actual pressure by the pressure signal measured and transmitted by a pressure sensor PS of the subject-to-control branch supply line, and a signal is transmitted to regulate the degree of opening of the division quantity controller FV so that the difference is reduced. Concretely, in the event that it is found with the comparison results that actual pressure is lower than set pressure, the degree of opening of the division quantity controller FV is made wider to raise pressure PT of the subject-to-control branch supply line. When the results of the comparison are found to be reverse, that is, actual pressure is higher than set pressure, the degree of opening of the division quantity controller FV is made narrower to lower pressure PT of the subject-to-control branch supply line.

[0043] Set pressure is determined beforehand by computation of the

relationships of supply flow rates of shower plates with pressure.

The set pressure ratio is determined from the results of the computation based on the flow rate ratio  $Q_2/Q_1$  supplied to branch supply lines GL<sub>1</sub> and GL<sub>2</sub> as shown in Table 2 and Table 3.

[0044] [Table 2]

[Set pressure ratio/Subject-to-control division quantity/Open/close valve operation command] to flow rate ratios PATTERN 1

Flow rate ratio $Q_2/Q_1$	Set pressure ratio $PI_2/PI_1$	Subject-to-control division flow quantity	Open/close valve operation command	
			OV <sub>1</sub>	OV <sub>2</sub>
4/1	2.079 > 1	PI <sub>1</sub>	Close	Open
3/1	1.795 > 1	PI <sub>1</sub>	Close	Open
2/1	1.473 > 1	PI <sub>1</sub>	Close	Open
1/1	1.041 > 1	PI <sub>1</sub>	Close	Open
1/2	0.736 < 1	PI <sub>2</sub>	Open	Close
1/3	0.601 < 1	PI <sub>2</sub>	Open	Close
1/4	0.520 < 1	PI <sub>2</sub>	Open	Close

[0045] [Table 3]

[Set pressure ratio/Subject-to-control division quantity/Open/close valve operation command] to flow rate ratios PATTERN 2

Flow rate ratio $Q_2/Q_1$	Set pressure ratio $PI_2/PI_1$	Subject-to-control division flow quantity	Open/close valve operation command
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			OV <sub>1</sub>	OV <sub>2</sub>
4/1	2.008 > 1	PI <sub>1</sub>	Close	Open
3/1	1.795 > 1	PI <sub>1</sub>	Close	Open
2/1	1.473 > 1	PI <sub>1</sub>	Close	Open
1/1	1.041 > 1	PI <sub>1</sub>	Close	Open
1/2	0.736 < 1	PI <sub>2</sub>	Open	Close
1/3	0.601 < 1	PI <sub>2</sub>	Open	Close
1/4	0.520 < 1	PI <sub>2</sub>	Open	Close

[0046] With the present embodiment, for shower plates (orifice plates) 3 and 4 of gas dischargers Dc and De, two sets of shower plate, that is, Dc<sub>1</sub> having 420 orifice holes 3a and Dc<sub>2</sub> having 480 orifice holes 3a are ready for the afore-mentioned shower plate 3 for the center part, and similarly another two sets of shower plate, that is, De<sub>1</sub> having 360 orifice holes 4a and De<sub>2</sub> having 476 orifice holes 4a are also ready for the shower plate 4 for the edge part.

[0047] Furthermore, the afore-mentioned flow rate ratio Q<sub>2</sub>/Q<sub>1</sub> can be set at 1/1, 1/2, 1/3, 1/4, 2/1, 3/1 or 4/1. Set pressure computed on this (or set pressure specified by the gas supply chamber side) and set pressure ratio are inputted to the input terminal T1.

[0048] As described later, set pressure and set pressure ratio listed in the above-shown Table 2 and Table 3 are determined by computing set pressure PI<sub>1</sub> and PI<sub>2</sub> on the upstream side of orifice holes 3a and 4a required to discharge the afore-mentioned specified flow quantities Q<sub>1</sub> and Q<sub>2</sub> of gas G judging with the bore sizes and numbers of orifice holes 3a and 4a of the shower plates 3 and 4

to be connected to the ends of branch gas supply lines. Further, it shows the ratio  $PI_2/PI_1$  determined by computing with necessary set pressure  $PI_2$  and  $PI_1$  on the upstream side obtained from the computation.

[0049] For combinations of the afore-mentioned shower plates 3 and 4, there are chosen beforehand a combination (hereinafter called Pattern 1) of a shower plate 3 having 420 orifice holes 3a and a shower plate 4 having 360 orifice holes 4a, and combination (hereinafter called Pattern 2) of a shower plate 3 having 480 orifice holes 3a and a shower plate 4 having 476 orifice holes 4a.

[0050] The relationship of the afore-mentioned division flow rates  $Q_1$  and  $Q_2$  and pressure  $PI_1$  and  $PI_2$  are formulated by using the following equations of conductance.

That is, the flow rate  $Q$  of gas passing through a pipe is expressed by  $Q=C \times (P_1-P_2) \dots (1)$  and  $C=182 \times D^4 \times (P_1 + P_2)/2 \times 1/L \dots (2)$ , where  $C$  represents a conductance (L/sec),  $D$  the diameter of a pipe (cm),  $L$  the length of a pipe (cm),  $P_1$  upstream pressure of a pipe (Torr),  $P_2$  downstream pressure of a pipe (Torr) and  $Q$  a flow rate (Torr · L/sec).

With the above equations (1) and (2), internal pressure ( $PI_1$  and  $PI_2$ ) on the upstream side of a shower plate is computed by using the outer diameter of the orifice hole of the shower plate as  $D$ , the length of the orifice hole of the shower plate as  $L$ , the internal pressure of a chamber ( $P_3 = 0.015$ Torr) as downstream side pressure  $P_2$ , and a flow rate per an orifice hole as a flow rate  $Q$  respectively.

[0051] Figure 3 is numerical values shown as a graph illustrating the relationships, in the event (Pattern 1) that a shower plate 3 of the gas discharger

Dc for the center part having 420 orifice holes with an internal diameter of 0.2mm  $\phi$  and a shower plate 4 of the gas discharger De for the edge part having 360 orifice holes with an internal diameter of 0.2mm  $\phi$  are combined, of a total flow rate (a whole flow rate) Q, control pressure PT<sub>1</sub> for the center part and control pressure PT<sub>2</sub> for the edge part are computed making a flow rate ratio (E/C=Q<sub>2</sub>/Q<sub>1</sub>) as a parameter. For example, in case of Q=1600, 1200, 800, 400 and 100SCCM at Q<sub>2</sub>/Q<sub>1</sub>=1, the mean value of the ratio Pl<sub>2</sub>/Pl<sub>1</sub> of control pressure Pl<sub>2</sub> on the edge part side and control pressure Pl<sub>1</sub> on the center part side becomes 1.041.

[0052] Similarly, Figure 4 is numerical values shown as a graph in the event (Pattern 2) that a shower plate 3 for a gas discharger Dc for the center part having 480 orifice holes with an internal diameter of 0.2mm  $\phi$  and a shower plate 4 for a gas discharger De for the edge part having 476 orifice holes with an internal diameter are combined. For example, in case of Q=1600, 1200, 800, 400 and 100SCCM at Q<sub>2</sub>/Q<sub>1</sub>, the mean value of the ratio Pl<sub>2</sub>/Pl<sub>1</sub> of control pressure Pl<sub>2</sub> on the edge part side and control pressure Pl<sub>1</sub> on the center part side becomes 1.001.

[0053] Table 2 and Table 3 illustrate all computed values that show the relationships of the flow rate ratio Q<sub>2</sub>/Q<sub>1</sub> and the ratio Pl<sub>2</sub>/Pl<sub>1</sub> of control pressure Pl<sub>2</sub> on the edge part side and control pressure Pl<sub>1</sub> on the center part side with Pattern 1 and Pattern 2 shown in Figure 3 and Figure 4. For example, Figure 3 shows that the ratio Pl<sub>2</sub>/Pl<sub>1</sub> of control pressure Pl<sub>2</sub> on the edge part side and control pressure Pl<sub>1</sub> on the center part side becomes mathematically 1.041 in case that combination of shower plates 3 and 4 to be used is made to be Pattern

1, and that the flow rate ratio  $Q_2/Q_1$  is 1.

[0054] A method for supplying gas while dividing to a chamber according to the present invention is explained hereafter. Referring to Figure 1 and Figure 2, both open/close valves  $OV_1$  and  $OV_2$  are fully closed in case that a starting signal is not inputted to a communication control circuit CT.

[0055] To supply a total quantity  $Q$  of gas while dividing at a specified ratio  $Q_2/Q_1$  (for example,  $Q_2/Q_1=1/2$ ), a total flow quantity  $Q$ , a combination pattern of shower plates 3 and 4 of gas dischargers  $D_c$  and  $D_e$  connected to the ends of branch supply lines  $GL_1$  and  $GL_2$ , and a desired flow rate ratio  $Q_2/Q_1$  are inputted to a communication control circuit CT. A control pressure ratio  $PI_2/PI_1$  corresponding to shower plates 3 and 4 and a flow rate ratio  $Q_2/Q_1$  is inputted as a set signal.

Next, a subject-to-control flow while dividing and a non-subject-to-control flow while dividing are determined by a communication control circuit CT based on given total quantity  $Q$ , a flow rate ratio  $Q_2/Q_1$  and set pressure  $PI_1$  and  $PI_2$ . Then an open/close valve  $OV$  of a non-subject-to-control branch supply line is opened, while an open/close valve  $OV$  of a non-subject-to-control branch supply line is closed.

[0056] For example, upon receiving a signal indicating a total flow rate  $Q$  of 1200SCCM, Pattern 1 of combination patterns of shower plate 3 and 4, a branch flow rate ratio  $Q_2/Q_1=1/2$ , set pressure  $PI_1$  and set pressure  $PI_2$ , a communication control circuit CT determines a branch supply line  $GL_1$  corresponding to  $PI_1$  which set pressure is set lower out of set pressure  $PI_1$  and  $PI_2$  to be a subject-to-control branch supply line, while a remaining branch supply

line GL<sub>2</sub> to be a non-subject-to-control branch supply line.

[0057] An open/close valve OV<sub>2</sub> of the non-subject-to-control branch supply line GL<sub>2</sub> is opened, while an open/close valve OV<sub>1</sub> of the subject-to-control branch supply line GL<sub>1</sub> is closed by the communication control circuit CT.

The communication control circuit CT compares set pressure PI<sub>1</sub> with actual pressure PT<sub>1</sub> by the pressure signal measured and transmitted by the pressure sensor PS<sub>1</sub> of the subject-to-control branch supply line GL<sub>1</sub>.

[0058] The communication control circuit CT compares set pressure PI<sub>1</sub> of a subject-to-control branch supply line GL<sub>1</sub> with actual pressure PT<sub>1</sub>, to transmit a signal to regulate the degree of opening of a division quantity controller FV to reduce the difference.

Namely, in the event that comparison results found that actual pressure PT<sub>1</sub> is lower than set pressure PI<sub>1</sub>, the degree of opening of the division quantity controller FV is made wider to raise pressure of the subject-to-control branch supply line PL<sub>1</sub>. With the reverse results that actual pressure PT<sub>1</sub> is higher than set pressure PI<sub>1</sub>, the degree of opening of the division quantity controller FV is made narrower to lower pressure of the subject-to-control branch supply line PL<sub>1</sub>.

[0059] With the communication control circuit CT, set pressure PI<sub>1</sub> of the subject-to-control branch supply line GL<sub>1</sub> and actual pressure are compared. When there is found no difference, or the difference is converged on the range of difference set in advance, the degree of opening of the division quantity controller FV is maintained, thus an automatic flow division control being completed.



Namely, a specified quantity  $Q$  of raw gas  $G$  from a gas supply source  $S$  is supplied to a wafer  $H$  into a chamber  $C$  through gas dischargers  $D_c$  and  $D_e$  while dividing at a specified flow rate ratio  $Q_1/Q_2$ .

[0060] Also, with the communication control circuit  $CT$ , set pressure  $PI_1$  and actual pressure  $PT_1$  are compared. When there is found no difference, or the difference is converged on the range of difference set in advance, the degree of opening of the division quantity controller  $FV$  is maintained, thus an automatic flow division control being completed. However, in the event that actual pressure  $PT_1$  fluctuates due to temperature changes or any other reasons, and the difference with set pressure  $PI_1$  comes to exceed the difference set in advance, a communication control circuit restarts to regulate the degree of opening of the division quantity controller  $FV$ .

[0061] With the embodiment, it is so constituted that a starting signal, a total flow quantity  $Q$ , a desired flow rate ratio  $Q_2/Q_1$ , combination patterns of shower plates 3 and 4, set pressure  $PI_1$  and  $PI_2$  and the like are inputted to a communication control circuit  $CT$  through a power source/signal input terminal. However, it can be so constituted that a communication control circuit  $CT$  determines a subject-to-control branch supply line and its set pressure from the signals of the afore-mentioned total flow quantity  $Q$ , a flow rate ratio  $Q_2/Q_1$  and the like and the data computed in advance.

#### Feasibility of Industrial Use

[0062] The present invention can be applied to facilities wherewith fluids are supplied while dividing under critical pressure conditions. For example, it can be utilized with a chamber in semiconductor manufacturing facilities or with a

chamber in facilities for manufacturing chemical or pharmaceutical products.